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(54) VARIABLE CAPACITY VANE PUMP WITH A ROTOR AND A CAM RING ROTATABLE ECCENTRICALLY RELATIVE TO A CENTER OF THE ROTOR

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F04C 2/00	(2006.01)
F04C 14/18	(2006.01)

(Continued)

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(58) **Field of Classification Search**
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USPC 418/24–28, 30, 259, 266–268
See application file for complete search history.

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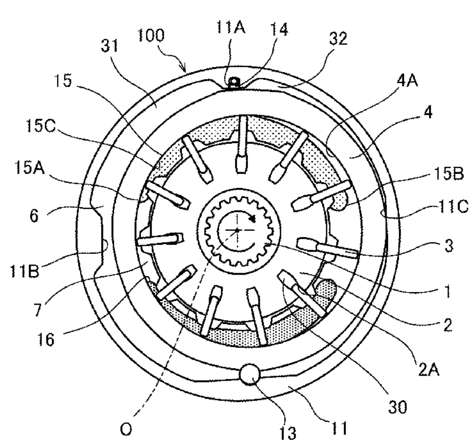
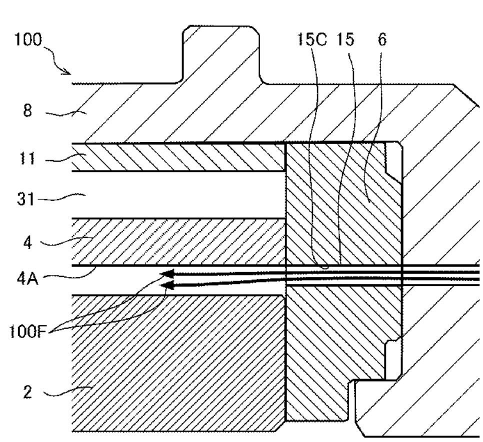
(57) **ABSTRACT**

In a variable capacity vane pump in which a discharge capacity of a pump chamber is varied by varying an amount of eccentricity of a cam ring relative to a rotor, a port inner wall surface that extends around an inner peripheral cam surface of the cam ring when the cam ring moves in a direction for increasing the amount of eccentricity of the cam ring relative to the rotor is formed on an intake port.

7 Claims, 5 Drawing Sheets





(51) **Int. Cl.**

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F04C 18/344	(2006.01)
F04C 2/344	(2006.01)
F04C 14/10	(2006.01)
F04C 14/08	(2006.01)

(52) **U.S. Cl.**

CPC *F04C 14/10* (2013.01); *F04C 2250/10* (2013.01); *F04C 2250/101* (2013.01)

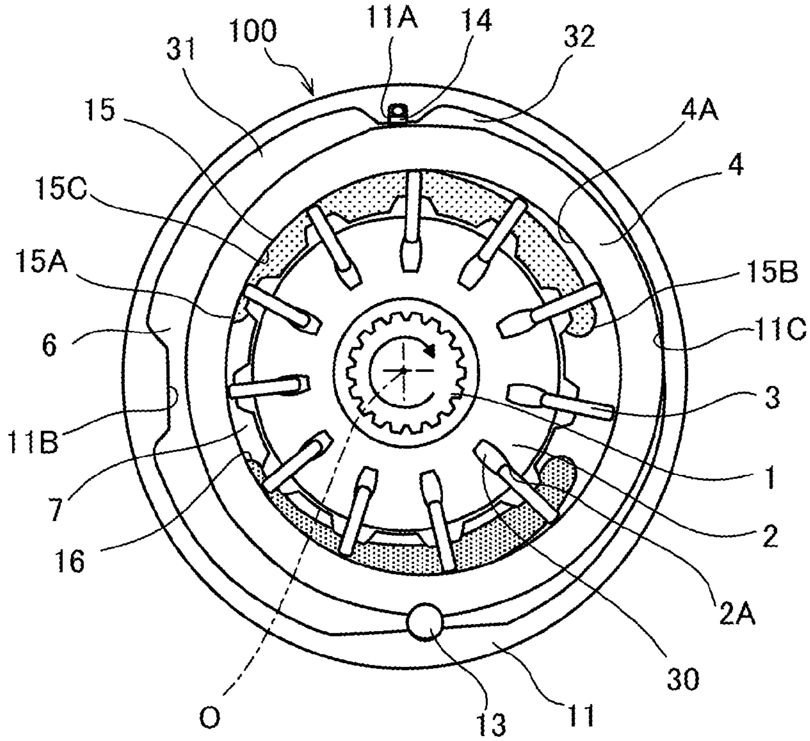
100
11A
14
32
31
15
4A
4
15C
15A
15B
11C
6
3
11B
1
7
2
16
2A
30
O
13
11

FIG.1A

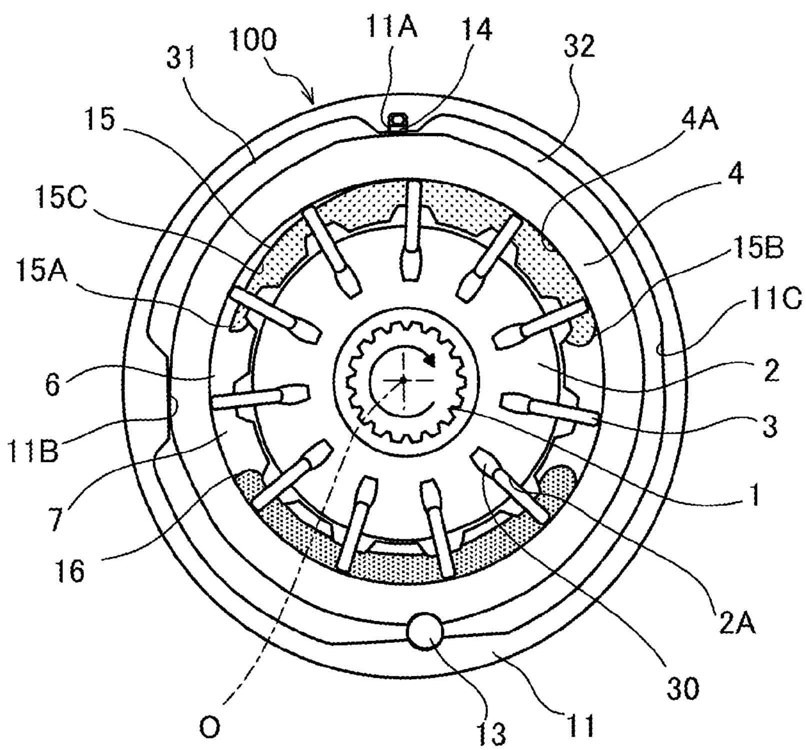
100
11A
14
32
31
15
4A
4
15C
15B
15A
11C
2
6
3
11B
1
7
16
2A
30
O
13
11

FIG.1B

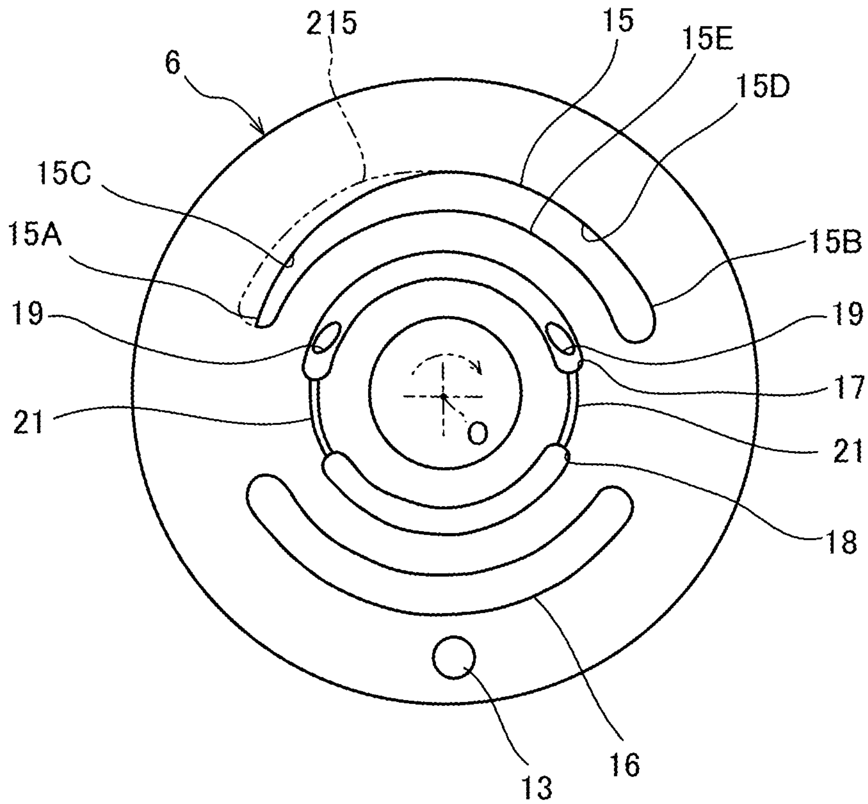

FIG.2

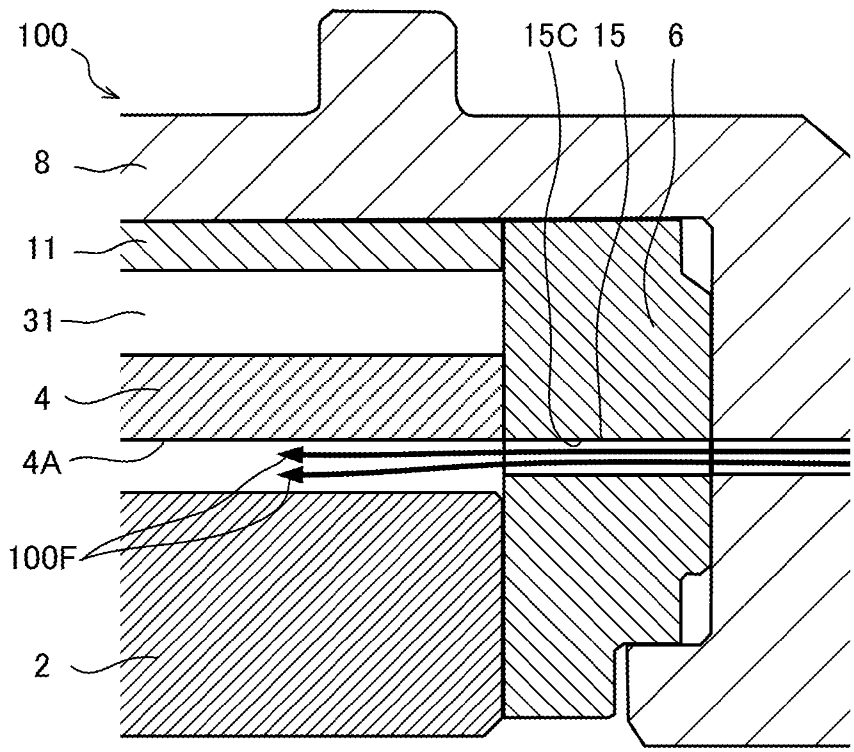
100
15C 15 6
8
11
31
4
4A
100F
2

FIG.3A

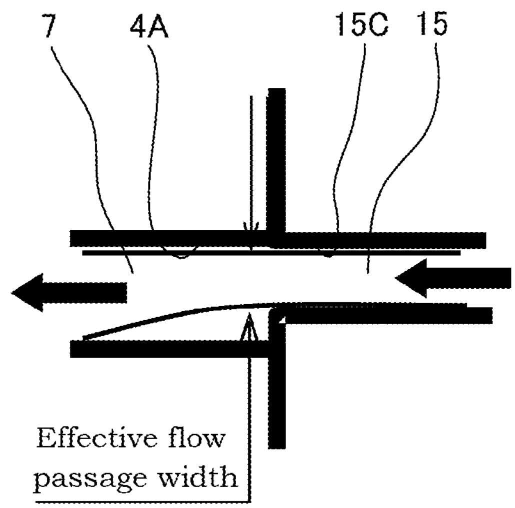
7 4A 15C 15
Effective flow
passage width

FIG.3B

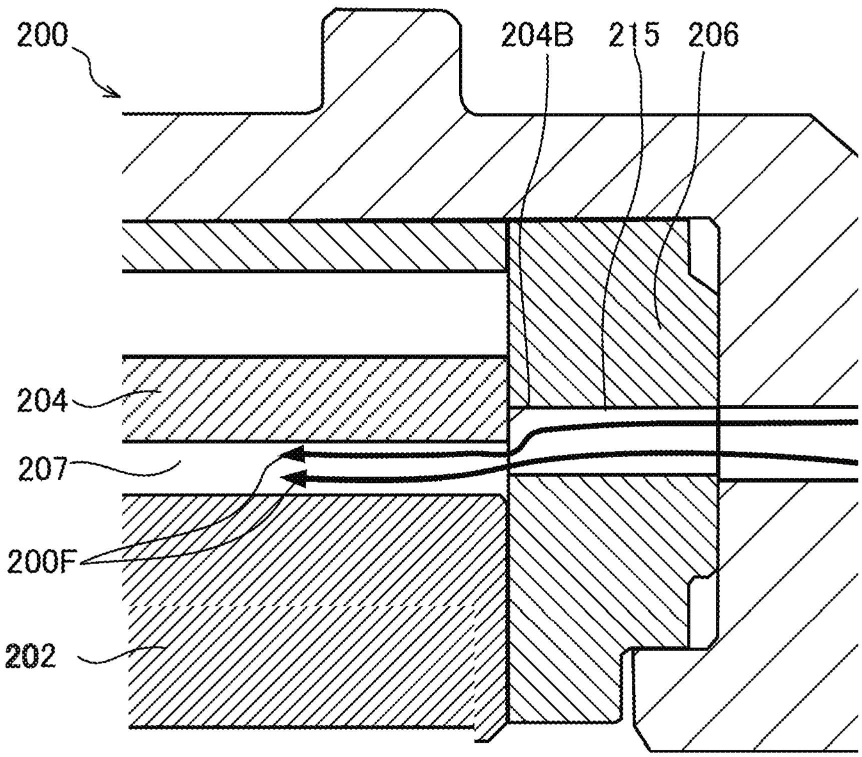

FIG.4A PRIOR ART

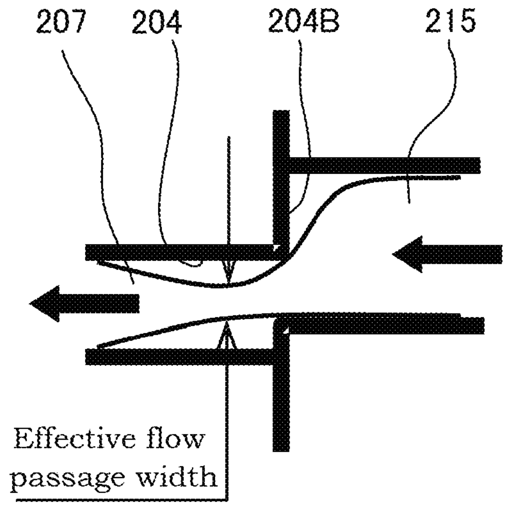

FIG.4B PRIOR ART

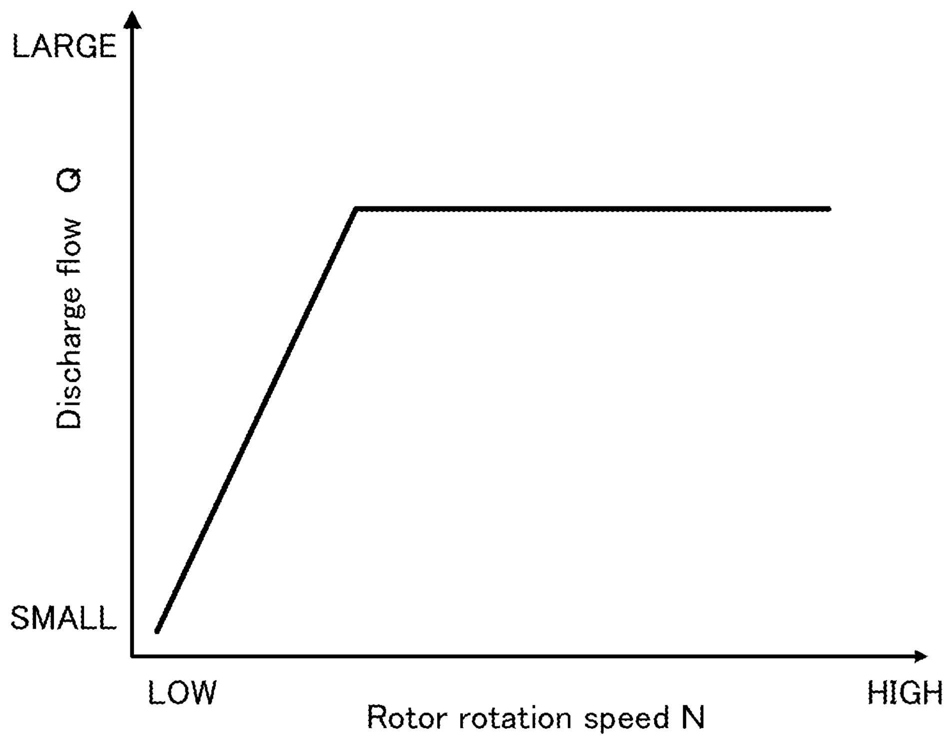
LARGE
Discharge flow Q
SMALL
LOW
Rotor rotation speed N
HIGH

FIG.5

VARIABLE CAPACITY VANE PUMP WITH A ROTOR AND A CAM RING ROTATABLE ECCENTRICALLY RELATIVE TO A CENTER OF THE ROTOR

TECHNICAL FIELD

The present invention relates to a variable capacity vane pump used as a fluid pressure supply source in a fluid pressure device.

BACKGROUND ART

In an example of this type of variable capacity vane pump, a cam ring swings using a pin as a fulcrum such that an amount of eccentricity of the cam ring relative to a rotor is varied, and as a result, a discharge capacity varies.

JP2011-140918A discloses a variable capacity vane pump in which a discharge port of the vane pump is formed so as not to interfere with a cam ring so that an opening area of the discharge port does not vary even when the cam ring moves.

SUMMARY OF INVENTION

In this type of variable capacity vane pump, as the cam ring moves, the cam ring forms a step that blocks a part of an intake port. Therefore, a working fluid suctioned into a pump chamber may impinge on the step, leading to an increase in pressure loss exerted on the working fluid, and as a result, cavitation may occur between the intake port and the pump chamber.

The present invention has been designed in consideration of this problem, and an object thereof is to prevent cavitation caused by a cam ring of a variable capacity vane pump.

According to one aspect of the present invention, a variable capacity vane pump used as a fluid pressure supply source includes: a rotor that is driven to rotate; a plurality of vanes housed in the rotor to be free to slide; a cam ring that includes an inner peripheral cam surface against which respective tip end portions of the vanes slide, and is capable of rotating eccentrically relative to a center of the rotor; a pump chamber defined between the rotor, the cam ring, and adjacent vanes; an intake port through which working fluid suctioned into the pump chamber is led; and a discharge port through which working fluid discharged from the pump chamber is led, wherein a port inner wall surface that extends around the inner peripheral cam surface of the cam ring when the cam ring moves in a direction for increasing an amount of eccentricity of the cam ring relative to the rotor is formed on the intake port.

Embodiments and advantages of the present invention will be described in detail below with reference to the attached drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1**A is a front view showing a condition in which a cam ring of a variable capacity vane pump according to an embodiment of the present invention is in a maximum eccentricity position.

FIG. **1**B is a front view showing a condition in which the cam ring of the variable capacity vane pump is in a minimum eccentricity position.

FIG. **2** is a front view of a side plate.

FIG. **3**A is a sectional view of the variable capacity vane pump.

FIG. **3**B is a pattern diagram showing a flow of working oil through the variable capacity vane pump.

FIG. **4**A is a sectional view of a conventional variable capacity vane pump.

FIG. **4**B is a pattern diagram showing a flow of working oil through the conventional variable capacity vane pump.

FIG. **5** is a characteristic diagram showing a relationship between a discharge flow and a rotation speed of a rotor of the variable capacity vane pump according to this embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

An embodiment of the present invention will be described below on the basis of the attached figures.

First, referring to FIGS. **1**A and **1**B, a variable capacity vane pump **100** according to this embodiment of the present invention will be described.

The variable capacity vane pump (referred to hereafter simply as the "vane pump") **100** is used as an oil pressure (fluid pressure) supply source for a hydraulic device (a fluid pressure device) installed in a vehicle, such as a power steering apparatus or a continuously variable transmission, for example.

The vane pump **100** is configured such that power from an engine (not shown) is transmitted to a drive shaft **1**, whereby a rotor **2** coupled to the drive shaft **1** rotates. In FIGS. **1**A and **1**B, the rotor **2** rotates clockwise, as shown by arrows.

The vane pump **100** includes a plurality of vanes **3** provided to be capable of reciprocating in a radial direction relative to the rotor **2**, and a cam ring **4** housing the rotor **2** and the vanes **3**.

Slits **2**A, each having an opening portion in an outer peripheral surface thereof, are formed in the rotor **2** radially at predetermined intervals. The vanes **3** are inserted into the slits **2**A to be free to slide. A vane back pressure chamber **30** into which a pump discharge pressure is led is defined on a base end side of each slit **2**A. The vanes **3** are pushed in a projecting direction from the slits **2**A by the pressure in the vane back pressure chambers **30**.

The drive shaft **1** is supported by a pump body **8** (see FIG. **3**A) to be free to rotate. A pump housing recessed portion is formed in the pump body **8** to house the cam ring **4**. A side plate **6** that contacts respective first side portions of the rotor **2** and the cam ring **4** is disposed on a bottom surface of the pump housing recessed portion. An opening portion of the pump housing recessed portion is sealed by a pump cover (not shown) that contacts respective second side portions of the rotor **2** and the cam ring **4**. The pump cover and the side plate **6** are disposed so as to sandwich the respective side faces of the rotor **2** and the cam ring **4**. A pump chamber **7** partitioned by the respective vanes **3** is defined between the rotor **2** and the cam ring **4**.

As shown in FIG. **2**, an intake port **15** that leads working oil into the pump chamber **7** and a discharge port **16** that extracts the working oil in the pump chamber **7** and leads the extracted working oil to the hydraulic device are formed in the side plate **6**. Specific shapes of the intake port **15** and the discharge port **16** will be described in detail below.

An intake port and a discharge port are also formed in the pump cover, not shown in the figures. The intake port and the discharge port of the pump cover communicate respectively with the intake port **15** and the discharge port **16** of the side plate **6** via the pump chamber **7**.

The cam ring **4** shown in FIGS. **1**A and **1**B is an annular member having an inner peripheral cam surface **4**A against which respective tip end portions of the vanes **3** slide. The inner peripheral cam surface **4**A is divided into an intake section into which working oil is suctioned through the intake port **15** as the rotor **2** rotates, and a discharge section from which working oil is discharged through the discharge port **16**.

The intake port **15** is formed in a semicircular shape in a circumferential direction of the drive shaft **1**. The intake port **15** communicates with a tank (not shown) via an intake passage (not shown). Working oil in the tank is supplied to the pump chamber **7** from the intake port **15** through the intake passage.

The discharge port **16** is formed in a semicircular shape on an opposite side to the intake port **15**. The discharge port **16** communicates with a high pressure chamber (not shown) that is formed in the pump body **8** so as to penetrate the side plate **6**. The high pressure chamber communicates with the hydraulic device (not shown) on the exterior of the vane pump **100** via a discharge passage (not shown). Working oil discharged from the pump chamber **7** is supplied to the hydraulic device through the discharge port **16**, the high pressure chamber, and the discharge passage.

As shown in FIG. **2**, back pressure ports **17** and **18** are formed in the side plate **6** to communicate with the vane back pressure chambers **30**. Grooves **21** that connect respective ends of the back pressure ports **17** and **18** to each other are formed in the side plate **6**. The back pressure port **17** communicates with the high pressure chamber via a through hole **19** penetrating the side plate **6**. Working oil pressure discharged from the pump chamber **7** is led into the vane back pressure chambers **30** through the discharge port **16**, the high pressure chamber, the through hole **19**, and the back pressure ports **17** and **18**. The vanes **3** are pushed in the projecting direction from the rotor **2** toward the cam ring **4** by the working oil pressure in the vane back pressure chambers **30**.

When the vane pump **100** is operative, the vanes **3** are biased in the projecting direction from the slits **2**A by the working oil pressure in the vane back pressure chambers **30**, which pushes the base end portions of the vanes **3**, and a centrifugal force that acts as the rotor **2** rotates. As a result, the tip end portions of the vanes **3** slide against the inner peripheral cam surface **4**A of the cam ring **4**.

In the intake section of the cam ring **4**, the vanes **3** sliding against the inner peripheral cam surface **4**A project from the rotor **2** such that the pump chamber **7** expands, and as a result, working oil is suctioned into the pump chamber **7** from the intake port **15**. In the discharge section of the cam ring **4**, the vanes **3** sliding against the inner peripheral cam surface **4**A are pushed in by the rotor **2** such that the pump chamber **7** contracts, and as a result, pressurized working oil in the pump chamber **7** is discharged through the discharge port **16**.

A configuration for varying a discharge capacity (a displacement capacity) of the vane pump **100** will now be described.

The vane pump **100** includes an annular adapter ring **11** that surrounds the cam ring **4**. A support pin **13** is interposed between the adapter ring **11** and the cam ring **4**. The cam ring **4** is supported by the support pin **13**. The cam ring **4** swings on an inner side of the adapter ring **11** eccentrically relative to a center O of the rotor **2** using the support pin **13** as a fulcrum.

A sealing material **14** against which an outer peripheral surface of the cam ring **4** slides while swinging is interposed in a groove **11**A of the adapter ring **11**. A first fluid pressure chamber **31** and a second fluid pressure chamber **32** are defined between the outer peripheral surface of the cam ring **4** and an inner peripheral surface of the adapter ring **11** by the support pin **13** and the sealing material **14**.

The cam ring **4** is caused to swing about the support pin **13** by a differential pressure between the first fluid pressure chamber **31** and the second fluid pressure chamber **32**. When the cam ring **4** swings, an amount of eccentricity of the cam ring **4** relative to the rotor **2** varies, leading to variation in the discharge capacity of the pump chamber **7**. When the cam ring **4** swings in a leftward direction from a condition shown in FIG. **1**A, the amount of eccentricity of the cam ring **4** relative to the rotor **2** decreases, leading to a reduction in the discharge capacity of the pump chamber **7**. When the cam ring **4** swings in a rightward direction from the condition shown in FIG. **1**B, on the other hand, the amount of eccentricity of the cam ring **4** relative to the rotor **2** increases, leading to an increase in the discharge capacity of the pump chamber **7**.

A limitation portion **11**B that limits movement of the cam ring **4** in the direction for reducing the amount of eccentricity relative to the rotor **2** and a limitation portion **11**C that limits movement of the cam ring **4** in the direction for increasing the amount of eccentricity relative to the rotor **2** are formed as respective bulges on the inner peripheral surface of the adapter ring **11**. The limitation portion **11**B prescribes a minimum amount of eccentricity of the cam ring **4** relative to the rotor **2**. The limitation portion **11**C prescribes a maximum amount of eccentricity of the cam ring **4** relative to the rotor **2**.

The vane pump **100** is further provided with a control valve (not shown) that controls the working oil pressure led into the first fluid pressure chamber **31** and the second fluid pressure chamber **32**. An orifice is provided in the discharge passage (not shown) communicating with the discharge port **16**. The control valve controls the working oil pressure led into the first fluid pressure chamber **31** and the second fluid pressure chamber **32** using a spool that moves in accordance with a front-rear differential pressure of the orifice. The control valve controls the working oil pressure in the first fluid pressure chamber **31** and the second fluid pressure chamber **32** such that the amount of eccentricity of the cam ring **4** relative to the rotor **2** decreases as a rotation speed of the rotor **2** increases.

FIG. **5** is a characteristic diagram showing a relationship between a rotation speed N and a discharge flow Q of the rotor **2** of the vane pump **100**. As shown on the characteristic diagram, in a low rotation speed region where the rotation speed N of the rotor **2** is lower than a predetermined value, the cam ring **4** is held in a maximum eccentricity position shown in FIG. **1**A, whereupon the discharge flow Q increases gradually as the rotation speed N of the rotor **2** increases. In a medium/high speed region where the rotation speed N of the rotor **2** exceeds the predetermined value, the cam ring **4** gradually moves in a direction for reducing the amount of eccentricity as the rotation speed N of the rotor **2** increases, whereby a further increase in the discharge flow Q is suppressed. It should be noted that by employing the orifice as a variable throttle that operates in conjunction with displacement of the cam ring **4**, the control valve can be set such that the discharge flow Q decreases gradually as the rotation speed N of the rotor **2** increases.

Next, referring to FIG. **2**, the intake port **15** according to this embodiment of the present invention will be described.

The intake port **15** is formed to extend in an arc shape about the center O of the rotor **2**. As shown in FIG. **1**B, when a center of the cam ring **4** and the center O of the rotor **2** are substantially aligned, or in other words when the amount of eccentricity of the cam ring **4** is substantially zero, the intake port **15** extends in an arc shape around the inner peripheral cam surface **4**A of the cam ring **4**.

The intake port **15** includes a communication start side intake port end portion **15**A at which communication with the pump chamber **7** starts as the rotor **2** rotates, and a communication end side intake port end portion **15**B at which communication with the pump chamber **7** ends as the rotor **2** rotates. A port inner wall surface **15**C is formed in the communication start side intake port end portion **15**A, and an opening width of the intake port **15** is formed to decrease gradually from a midpoint of the intake port **15** toward a tip end of the communication start side intake port end portion **15**A.

The port inner wall surface **15**C is formed in the communication start side intake port end portion **15**A so as to extend around the inner peripheral cam surface **4**A of the cam ring **4** when the cam ring **4** moves (swings) in the direction for increasing the amount of eccentricity relative to the rotor **2**, as shown in FIG. **1**A. The port inner wall surface **15**C is configured to deviate gradually from the inner peripheral cam surface **4**A of the cam ring **4** as the cam ring **4** moves (swings) in the direction for reducing the amount of eccentricity relative to the rotor **2**.

On the front view shown in FIG. **2**, the port inner wall surface **15**C is formed as a curved surface bent into an arc shape that is substantially identical to the shape of the inner peripheral cam surface **4**A of the cam ring **4** in the maximum eccentricity position.

The port inner wall surface **15**C is formed to extend in a direction parallel to a rotation axis of the rotor without a step relative to the inner peripheral cam surface **4**A of the cam ring **4** when the cam ring **4** is in the maximum eccentricity position shown in FIG. **1**A.

An opening width of the communication end side intake port end portion **15**B, meanwhile, is formed to be substantially constant from the midpoint of the intake port **15** to the vicinity of a tip end of the communication end side intake port end portion **15**B.

A port inner wall surface **15**D that extends around the inner peripheral cam surface **4**A of the cam ring **4** when the cam ring **4** moves to a position in which the amount of eccentricity relative to the rotor **2** is at the minimum is formed in the communication end side intake port end portion **15**B. The port inner wall surface **15**D and the inner peripheral cam surface **4**A of the cam ring define a flow passage through which the working fluid flows rectilinearly when the cam ring is in the minimum eccentricity position.

The port inner wall surface **15**D is formed as a curved surface bent into an arc shape that is substantially identical to the shape of the inner peripheral cam surface **4**A of the cam ring **4** in the minimum eccentricity position.

As described above, an outer peripheral side inner wall surface of the intake port **15** is constituted by the port inner wall surface **15**C that extends around the inner peripheral cam surface **4**A in the maximum eccentricity position, and the port inner wall surface **15**D that extends around the inner peripheral cam surface **4**A in the minimum eccentricity position.

An inner peripheral side inner peripheral surface **15**E of the intake port **15** is formed as a curved surface bent into an arc shape that extends around an outer peripheral portion of the rotor **2**.

Next, referring to FIGS. **3**A to **4**B, actions and effects of the vane pump **100** according to this embodiment will be described while providing comparisons with a conventional vane pump **200**.

As shown by a dot-dot-dash line in FIG. **2**, an intake port **215** of the conventional vane pump **200** is formed such that an opening width thereof is substantially constant from a circumferential direction midpoint of the intake port **215** to the vicinity of a tip end of a communication start side intake port end portion.

FIG. **4**A is a sectional view of the conventional vane pump **200**, and FIG. **4**B is a pattern diagram illustrating a flow of working oil through the intake port **215**.

In the conventional vane pump **200**, as shown in FIGS. **4**A and **4**B, when a cam ring **204** is in a position where an amount of eccentricity relative to a rotor **202** increases, a step **204**B is formed by the intake port **215** formed in a side plate **206** and a pump chamber **207**. As a result of the step **204**B, a part of the intake port **215** is blocked by the cam ring **204** such that working oil suctioned into the pump chamber **207** impinges on the step **204**B, leading to a large curve in a flow line **200**F of the working oil. Accordingly, an apparent flow passage width (referred to hereafter as an "effective flow passage width") of a flow passage formed between the intake port **215** and the cam ring **204** decreases. Hence, pressure loss exerted on the flow of the working oil increases, and as a result, cavitation may occur between the intake port **215** and the pump chamber **207**.

FIG. **3**A is a sectional view of the vane pump **100** according to this embodiment, and FIG. **3**B is a pattern diagram illustrating a flow of working oil through the intake port **15**.

In the vane pump **100** according to this embodiment, as shown in FIGS. **3**A and **3**B, when the cam ring **4** is in a position where the amount of eccentricity relative to the rotor **2** increases, the port inner wall surface **15**C of the intake port **15** formed in the side plate **6** extends without a step relative to the inner peripheral cam surface **4**A of the cam ring **4**. Hence, the working oil suctioned into the pump chamber **7** flows directly around the port inner wall surface **15**C and the inner peripheral cam surface **4**A such that a flow line **100**F thereof extends rectilinearly. Accordingly, the effective flow passage width of the flow passage formed between the intake port **15** and the cam ring **4** does not decrease, and therefore pressure loss exerted on the flow of the working oil can be suppressed. As a result, cavitation between the intake port **15** and the pump chamber **7** can be prevented.

When the vane pump **100** is in the operating condition shown in FIGS. **3**A and **3**B in the rotation speed region of the characteristic diagram shown in FIG. **5** where the discharge flow Q gradually increases as the rotation speed N of the rotor **2** increases, the pressure loss generated in the working oil flowing to the pump chamber **7** is suppressed. Likewise in the rotation speed region exceeding this rotation speed region, where the cam ring **4** swings in the direction for reducing the amount of eccentricity, an opening area of the intake port **15** does not vary, and therefore a step is not formed between the cam ring **4** and the intake port **15** in the flow passage of the working oil flowing to the pump chamber **7**. As a result, the pressure loss generated in the working oil flowing to the pump chamber **7** is suppressed.

According to the embodiment described above, following actions and effects are obtained.

(1) The port inner wall surface **15**C is formed in the intake port **15** so as to extend around the inner peripheral cam surface **4**A of the cam ring **4** when the cam ring **4** moves in the direction for increasing the amount of eccentricity of the cam ring **4** relative to the rotor **2**. Hence, pressure loss generated when working fluid suctioned into the pump chamber **7** through the intake port **15** impinges on a step in

the cam ring **4** can be suppressed, and as a result, cavitation can be prevented from occurring between the intake port **15** and the pump chamber **7**.

(2) The intake port **15** is formed such that the port inner wall surface **15**C extends without a step relative to the inner peripheral cam surface **4**A of the cam ring **4** when the cam ring **4** moves to the maximum eccentricity position. Hence, the working fluid suctioned into the pump chamber **7** flows directly around the port inner wall surface **15**C and the inner peripheral cam surface **4**A such that pressure loss exerted on the flow of the working fluid is suppressed.

(3) The intake port **15** includes the communication start side intake port end portion **15**A at which communication with the pump chamber **7** starts as the rotor **2** rotates, and the communication end side intake port end portion **15**B at which communication with the pump chamber **7** ends as the rotor **2** rotates. Further, the port inner wall surface **15**C is formed in the communication start side intake port end portion **15**A, and the opening width of the intake port **15** is formed to decrease gradually from the midpoint of the intake port **15** toward the tip end of the communication start side intake port end portion **15**A. Hence, the opening area of the intake port **15** does not vary even when the cam ring **4** moves in the direction for reducing the amount of eccentricity, and as a result, a step can be prevented from forming between the cam ring **4** and the intake port **15** in the flow passage through which the working fluid is suctioned into the pump chamber **7**.

An embodiment of the present invention was described above, but the above embodiment is merely examples of applications of the present invention, and the technical scope of the present invention is not limited to the specific constitutions of the above embodiment.

The application claims priority based on Japanese Patent Application No. 2012-062309, filed with the Japan Patent Office on Mar. 19, 2012, the entire contents of which are incorporated herein by reference.

INDUSTRIAL APPLICABILITY

The variable capacity vane pump according to the present invention can be used in a fluid pressure device such as a power steering apparatus or a continuously variable transmission, for example.

The invention claimed is:

1. A variable capacity vane pump comprising:

a rotor configured to be driven to rotate;

a plurality of vanes housed in the rotor to be free to slide;

a cam ring comprising an inner peripheral cam surface against which respective tip end portions of the vanes are slidable, said cam ring being configured to rotate eccentrically relative to a center of the rotor;

a pump chamber defined by the rotor and the cam ring in between adjacent vanes;

an intake port having an arc shape around the center of the rotor and being configured to lead working fluid into the pump chamber, said intake port comprising:

a first port inner wall surface having a shape that corresponds to a shape of the inner peripheral cam surface of the cam ring in a maximum eccentricity position; and

a second port inner wall surface having a shape that corresponds to a shape of the inner peripheral cam surface of the cam ring in a minimum eccentricity position; and

a discharge port configured to lead the working fluid from the pump chamber,

wherein

the intake port comprises:

a communication start side intake port end portion at which communication with the pump chamber starts as the rotor rotates; and

a communication end side intake port end portion at which communication with the pump chamber ends as the rotor rotates,

the first port inner wall surface is in the communication start side intake port end portion, and

the second port inner wall surface is in the communication end side intake port end portion.

2. The variable capacity vane pump as defined in claim **1**, wherein, when the cam ring is in the maximum eccentricity position, the first port inner wall surface extends in a direction parallel to a rotation axis of the rotor without a step relative to the inner peripheral cam surface of the cam ring.

3. The variable capacity vane pump as defined in claim **2**, further comprising:

a side plate configured to contact a side portion of the rotor and a side portion of the cam ring when the side plate is housed in the pump chamber.

4. The variable capacity vane pump as defined in claim **1**, wherein

an opening width of the intake port is configured to decrease gradually from a midpoint of the intake port toward a tip end of the communication start side intake port end portion.

5. The variable capacity vane pump as defined in claim **1**, further comprising:

an adapter ring surrounds the cam ring; and

a support pin interposed between the adapter ring and the cam ring,

wherein the cam ring is configured to swing, with the support pin as a fulcrum, inside the adapter ring and eccentrically relative to the center of the rotor.

6. The variable capacity vane pump as defined in claim **5**, wherein the adapter ring comprises:

a first limitation configured to limit movement of the cam ring in a direction for reducing an amount of eccentricity relative to the center of the rotor; and

a second limitation configured to limit movement of the cam ring in a direction for increasing the amount of eccentricity relative to the center of the rotor.

7. The variable capacity vane pump as defined in claim **1**, wherein

the first port inner wall surface and the inner peripheral cam surface of the cam ring define a flow passage through which the working fluid flows rectilinearly when the cam ring is in the maximum eccentricity position, and

the second port inner wall surface and the inner peripheral cam surface of the cam ring define a flow passage through which the working fluid flows rectilinearly when the cam ring is in the minimum eccentricity position.

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